ASSESSMENT OF LIQUEFACTION/REFRIGERATION OF MARS IN SITU PROPELLANT PRODUCTION. Allen Mac Knight and Leon Schipper, AlliedSignal Aerospace Systems & Equipment Torrance California 90504-6099, USA.

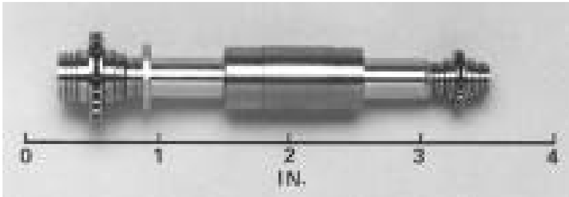
Abstract: This paper presents an assessment of various means of liquid storage of potential propellants manufactured in situ from the Martian atmosphere applicable to rover and/or return to earth mission. In situ potential production of two types of bipropellants, namely the use of either methane and carbon monoxide (obtained through different processes), and oxygen as oxidizer are considered. Design considerations and implications for both direct prototype liquefaction and application of refrigeration to condense, pump if required, the specific propellant prior to storage are reviewed. In the present assessment efforts were primarily associated with the liquefaction or refrigeration of oxygen.

In a typical liquefaction cycle the oxygen is compressed, cooled in a series of heat exchangers, and partially liquefied through a Joule-Thompson expansion. The high operating pressure is best obtained via the application of CO_2 adsorption pressure beds located at the inlet of the supplied CO_2 stream and augmented pressurization, if required, through the use of multi-stage compressor assembly. Sensible heat sink removal capability is provided by the separated oxygen vapor stream augmented by thermal radiation to the Mars environment. Additional cooling can be obtained from hydrogen supplied if methane is formed, turbo expansion, or augmented refrigeration. This concept is rather complex and requires excessive input power.

The present required cooling load (sensible and phase change) is such that the use of a reversed Brayton refrigeration cycle, of single expander, is most competitive, in terms of power requirement, associated weight, and potential long operation. Accordingly, evaluation emphasis was placed on this concept to provide the required liquefaction. In a reversed Brayton single expander cycle a gaseous working fluid is compressed and then cooled by rejecting heat to the surroundings; further cooling is obtained by recuperative heat exchange with gas returning to the compressor. The cooled high-pressure gas is expanded through a turbine producing cold, low pressure gas that provides the required refrigeration. Refrigerator performance characterization were determined including variation in operational pressure of the gaseous oxygen stream, and change in molecular weight to achieve desired performance potentials of the involved turbine and compressor assemblies.

The long term operation is provided via the application of self reliant gas bearing (requiring no external lubrication or coolant of the rotating assembly). Under the development of a dual expander, known as the Mini-Halo Turborefrigerator, 9291 hrs of testing were accomplished inclusive of the completion of 7400 hr of endurance system testing. Subsequently a three stage expansion, capable of cooling further lower temperature loads was developed. Use of self reliant fluid bearing, in addition to assembly simplicity, allows high speed rotation such that desirable turbomachinery performance are realized. Prototype hardware of the Mini-Halo, used in the endurance test is shown in the Figures below.

Motor-Compressor
125,000 RPM/1.8 in Dia.



Turboalternator
200,000 RPM/0.4 in Dia.

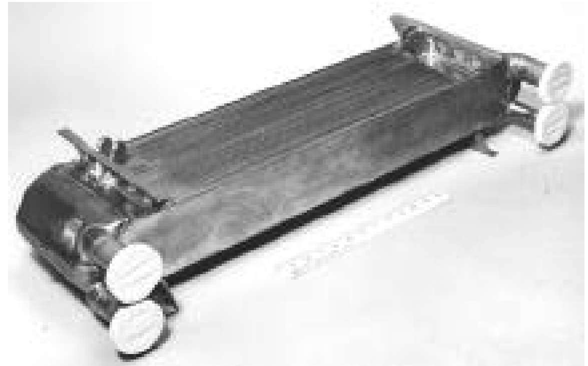


Plate-fin Recuperator
0.98 Effectiveness